Line Design Principles - Specification

Table of contents

1. Introduction

1.1 Purpose

The purpose of this specification is to define the design principles for Powerlink's overhead transmission line assets to ensure they are designed in such a manner to meet legislative requirements and to ensure safe and cost effective construction, operation and maintenance over the nominated design life. The intent is that that internal and external Engineering Design Service Providers, Maintenance Service Providers and Construction Contractors shall use this specification in conjunction with relevant specifications, guidelines and equipment strategies.

1.2 Scope

This asset management specification outlines the high-level design requirements for all Powerlink's overhead transmission lines at high and extra high operating voltages, nominally between 110kV to 500kV. Each transmission line consists of a series of interconnected critical assets each of which is considered to include:

- structures including foundations;
- insulator assemblies;
- conductors and fittings; and
- overhead earthwires and fittings, and earthing.

Design work referenced in this Specification shall be in accordance with the RPEQ Definitions (Powerlink Context) Framework and Safety in Design (SiD) Procedure to ensure all safety, performance, environmental and legislative aspects relating to the construction, operation, maintenance and demolition requirements of the asset.

This document shall apply to design associated with projects and not be applied retrospectively. There will be instances where designers will not be able to meet all requirements specified in this document and will recommend non-standard design solutions based on specific site constraints and/or customer's requirements. These non-standard design solutions shall still comply with the relevant standards, codes, regulations and guidelines and will be subjected to the Safety in Design process. All non-standard design solutions will be reviewed and agreed to by Lines Strategies.

Easement, vegetation management and assets with no enduring needs are not included in the scope of this document.

1.3 References

Document code	Document title
AEMC	National Electricity Rules
Australian Standard AS 3891.1 & 2	Air Navigation – Cables and their supporting structures
Australian Standard AS 3891	Air navigation – Cables and their Supporting Structures, parts 1 & 2
Australian Standard AS 4312	Atmospheric Corrosivity zones in Australia
Australian Government	Civil Aviation Safety Regulations 1998 (Compilation No. 94)
ENA Doc 025-2022	EG-0 Power System Earthing Guide - Part 1: Management Principles
ENA Doc 047-2022	Guideline for Wind Turbines Proximity to Electricity Transmission Lines
Australian Standard AS/NZS 4853	Electrical Hazards on Metallic Pipelines

Document code	Document title
State of Queensland	Electrical Safety Code of Practice 2020
State of Queensland	Electrical Safety Code of Practice for Works 2020 Electrical Safety Code Of Practice 2020 – Working near overhead and underground electric lines
State of Queensland	Electricity Act 1994
Australian Standard AS 5804	High Voltage Live Working
Australian Standard AS 5804	High voltage Live Working
International Commission On Non-Ionizing Radiation Protection	ICNIRP Guidelines: Non-Ionising Radiation Protection Guideline
Australian Standard AS/NZS 1891	Industrial Fall arrest Systems and Devices parts 1, 2,3 and 4
Australian Standard AS 1154	Insulator and Conductor Fittings for Overhead Power Lines
Australian Standard AS 1154	Insulator and conductor Fittings for Overhead Power Lines
Australian Standard 1170.2	Structural Design Actions – Wind Actions
Australian Standard AS 3995	Design of Steel Lattice Towers and Masts
Australian Standard AS/NZS 7000	Overhead Line Design – Detailed Procedures
Australian Standard AS/NZS HB 331: 2020	Overhead Line Design Handbook 331: 2020
State of Queensland	Queensland Electrical Safety Act 2002
State of Queensland	Queensland Electrical Safety Regulation 2013
Australian Standard AS/NZ ISO 31000	Risk Management – Principles & Guidelines
International Electrotechnical Commission IEC TS 60815	Selection and Dimensioning of High Voltage Insulators intended for use in polluted conditions
State of Queensland	Work Health and Safety Act 2011

1.4 Defined terms

Terms	Definition
ADSS	All Dielectric Self-Supporting (cable)
AGL	Above Ground Level
AGSU	Armour Grip Suspension Unit is hardware used to hold the conductor or earthwire in suspension arrangements.
As-Built	The asset as constructed
BOM	Bill of Materials
CASA	Civil Aviation Safety Authority
CMMS	Computerised Maintenance Management System
Design Brief	A document issues by Powerlink setting out the essential design requirements for a new transmission line
ENA	Energy Networks Association
EPV	Elevated Platform Vehicle
ESAA	Energy Supply Association of Australia
Fires	Bushfires/wildfires, grass fires, “controlled burns”, and cane fires.
GIS	Geographic information System (Smart Client)
Grade 2 Corrosion	Defined as the “Initial onset of rust – light rust in the form of scattered pinholes, up to the equivalent to AS/NZS 2312 2% level.”
Grade 3 Corrosion	Defined as the “Breakdown of the protective coating. Bare, rusting steel over most of the surface, with isolated traces of remaining galvanising. The steel surface is rough but not pitted, exceeding AS/NZS 2312 50% level.”
Grade 4 Corrosion	Defined as the “Complete rusting of the steel surface. Minor or deep pitting of bare steel leading to noticeable reduction of cross-section.”
HTC and HTLS	High Temperature Conductor and High Temperature Low Sag (conductor)
OD	Outside Diameter
OHEW	Overhead Earthwire
OPGW	Optical Fire Ground Wire/Optical Pilot Ground Wire.
Legacy Structures	Transmission Line structures designed and constructed before the approval of this current document that do you comply with the current industry standards or practices.
Maintenance Manual	Document documenting all maintenance data (held in Powerlink’s document management system (Objective)
MEN	Multiple Earthed Neutral (MEN) earthing system
PLS-CADD	Line layout design software system
Project	Has the meaning given to that term in the WHS legislation
PRS	Portfolio Risk System
RCM	Reliability Centred Maintenance

Terms	Definition
SAP	Powerlink's Asset Management System – SAP "Systems Application and Products in data processing"
SCADA	Supervisory Control And Data Acquisition
SVD	Spiral Vibration Damper
SAMP	Strategic Asset Management Plan
SFAIRP	So far as is reasonably practical
RPEQ	Registered Professional Engineer Of Queensland. Has the meaning in the RPEQ Laws
RPEQ Laws	means all legislation relating to the provision of professional engineering services and the regulation of the engineering profession in Queensland and includes the Professional Engineers Act 2002 (Qld) and the Code of Practice for Registered Professional Engineers in Queensland as amended or replaced from time to time.
RPV	Remotely piloted vehicle
WHS Legislation	Means the *Work Health and Safety Act 2011* (Qld), the *Work Health and Safety Regulation 2011* (Qld) and (where applicable) the *Work Health and Safety Act 2011* (Cth) or the equivalent work health and safety legislation in any relevant jurisdiction.

2. General Overview

2.1 Purpose of and Need for Design

Since transmission lines are built on both public and private land, protected only by easement rights, the failure of a transmission line can have serious safety and reputational consequences to Powerlink as well as members of the public and can result in significant interruption of electrical supply to a wide region for extended periods.

These lines are composed of many mechanical and structural elements all of which are subject to strength deterioration resulting from age, wear and corrosion.

Rates of deterioration vary widely depending on the operating environment of the transmission, as do weather and other environmental conditions. It is essential that all aspects of the transmission line (including material type) are carefully considered in a design process to ensure that all aspects of the line are compliant to all relevant engineering standards and legislation, and will reach the design life with minimal intervention.

2.2 Asset Management

The role of Powerlink's Asset Management Strategy is to ensure the organisation's assets are managed in a manner consistent with its purpose to connect Queenslanders to a world-class energy future. Powerlink's asset management practices seek to drive efficiency whilst effectively managing safety, reliability, customer expectations and other risks across Powerlink's portfolio of regulated, negotiated and non- regulated assets. Powerlink's Network Vision and Business Strategy capture the significant external and internal drivers on our business and the network and set out the strategic direction to be adopted by the business. In the context of transmission lines, Asset Management involves the condition monitoring of the transmission line components, and arranges for their repair or replacement to ensure that the line will continue to function effectively and safely for its design lifetime. The development of an effective preventative maintenance program depends largely on what happens at the design stage.

The design of each of the critical asset categories of a new transmission line as described in Section 1.2 above shall consider a Reliability-Centred Maintenance (RCM) or similar process to determine appropriate components to match the required life and reliability of the asset. The outputs of this assessment are to include:

- routine Inspections including condition based monitoring and failure investigations
- failure investigations
- overhaul or replacement of components
- redesign of equipment or procedures (where required).

2.3 Planning

2.3.1 System Planning

Planning a new transmission line requires nominating the structure type, conductor, OPGW and earthwire, operating voltage, the number of circuits and the line's intended function, whether it is for a system reinforcement, an interconnector, a network extension, or a customer connection. These criteria will include any specific requirements for the application, including the line's criticality, availability, operating performance, electrical loading capability, and any non-standard considerations. The planning process shall also consider providing appropriate solutions that meet the expectations of the wider community and include, where appropriate, a comparative assessment on the viability of alternative underground cable solutions with considerations to the whole-of-life costs and technical, operational, environmental and social licence impacts.

2.3.2 Design for Operational Integrity

All new transmission lines shall be designed to minimise the risk to their operational integrity, and to maximise their accessibility for construction and maintenance.

Operational integrity requires a consideration of the number of circuits on the selected easement, and the potential impact of both on-easement and off-easement incidents. Within the easement corridor, land use is constrained in accordance with standard easement conditions. However, when the easement contains a double circuit line, lightning can potentially cause an outage on both circuits. Should there be more than one transmission line on the easement the potential exists for a failure of one structure to impact an adjacent structure. Whilst these are low probability events, the implications are to be considered.

In deciding whether a new line is to be co-located with an existing line, matters that need to be considered include:

- the criticality of the new line either to a customer or to the system integrity
- the security of both the new line and the existing line(s)
- the length in parallel and hence the potential impact of a common mode failure
- the likely community response to the proposal
- the environmental impact of the proposal
- common access advantages
- cost.

The operation of any transmission line may be affected by external factors and events such as fire, vehicle collision, fauna and flora and the failure, operation or maintenance of third party assets in the vicinity. Procedures for minimising the potential impact for circuit outages are detailed below.

Numerous design principles have a significant impact on the reliability of a transmission line, including but not limited to the structural resilience and security, clearances (Powerlink assets, third parties assets, structures and ground), insulation co-ordination and lightning performance. The structural security is the reliability of the structure or probability that a structural system performs a given mechanical purpose, under a set of conditions, during a reference period. The structural security can be impacted by various factors and events, such as cyclones, microbursts, flooding, poor condition, bushfires or inadequate design. Impacts of these factors and events are managed mainly through the easement acquisition and planning process and then the detailed design criteria and processes, including Safety in Design.

The minimum design return periods shall be in accordance with Table 6.1 of AS/NZS 7000 with a line security level III, with the exception of the 500kV network and greenfield state-interconnectors, which shall be designed with a higher security level based on a 1 in 300 year wind return period. In specific circumstances a different return period may be proposed to the Asset Strategies group for consideration, under the following circumstances:

- Reduced line security level for assets with a reduced design working life
- Increased line security for crossings of critical Powerlink or third party assets or other special circumstances where standards are deem not adequate or appropriate.

2.3.2.1 Aircraft Collision

To reduce the risk of an aircraft colliding with a transmission line, the following processes are to be implemented wherever there are defined opportunities for routine aviation activities within defined distances depending on the type of aerodrome or landing area in accordance with CASA classifications. Typical activities might include landing and taking off, agricultural aerial work, and scenic valleys where aircraft or balloons operate, or known areas of high bushfire risk where aerial water bombing may be required or has historically operated:

- Aviation activities in the vicinity of a new line route must be identified during the route selection process, and potentially impacted third parties included in the consultation process. Details of what and where aviation activities may be impacted must be passed to the designers to ensure provision is made for appropriate hazard control measures. Those details must also be recorded in the impacted property files.
- Details of airfields and known local landing areas must be recorded and classified in Powerlink's GIS system in accordance with the latest in-force definitions in CASA and Civil Aviation Safety Regulations.
- Details of structures within 30 km of Defence aviation areas must be recorded in Powerlink's GIS system.
- The height and location of overhead transmission lines in the vicinity of CASA approved aircraft landing areas must meet the constraints and marking requirements set out in CASA's protected surface designations in accordance with applicable distances from aerodromes or other landing areas defined in AS3891.1. Once construction has been committed, impacted aviation parties must be advised, including:
  - official Government organisations responsible for regulating aviation activities
  - organisations responsible for publishing airstrip directories
  - requirements for publishing the location of structures 100 m AGL in the Air Services Australia Tall Structures database
  - owners of identified airstrips in the vicinity of the new transmission line.

2.3.2.2 Third-Party Assets & Structures

Third party assets and structures such as trees or tree branches, or man-made structures impacting the transmission line directly present a risk to the safe operation and reliability of the network. Tree-related incidents can be minimised by following up on regular line patrol reports identifying developing tree-risk situations and undertaking control measures as detailed in Powerlink's Vegetation Management Specification.

The risk of a man-made structure failure impacting an adjacent transmission line, can only be avoided by ensuring adequate separation between the structure and the line. For wind turbines, Powerlink requires where possible a setback of turbine blade tip height from edge of easement, although this separation may not be sufficient for a turbine blade throw scenario.

Separation distances and recommendations outlined in ENA Doc 047-2022 Guideline for Wind Turbines Proximity to Electricity Transmission Lines, shall be adhered to where practical to do so.

2.3.2.3 Fires

It is possible for a fire traversing the easement corridor to be sufficiently severe as to cause air insulation failure on adjacent circuits either successively or simultaneously. Whilst there exists no fail-safe design mechanism to guarantee line operational security from a fire crossing the easement, there are certain design, operational and vegetation control measures that are to be implemented in fire prone areas to reduce the risk– as described in the Vegetation Management Specification.

For vegetation control, follow Powerlink's Vegetation Management Specification, and in particular, to control the risk or to reduce the impact of a fire, the measures detailed in Section 2.8 Fire Risk Management.

For operational control, both controlled burns by competent authorities' and cane fires by responsible canegrowers, require awareness on the part of the burner as to the risk of a flashover. They have a responsibility to make Powerlink or their local representative aware of their intention. Both of these activities require Powerlink to be proactive in raising awareness among the parties. An awareness of a potential fire impacting a line can allow the operating authority to be prepared for a possible incident affecting that transmission line.

Cane fires are deliberately set on private land as part of a normal harvesting operation in some cane-growing areas. Powerlink's public brochures advise farmers to cut green in a band 25m each side of a transmission line and to burn away from that cleared band. Even exercising due diligence in the harvesting operation there is no practical way of ensuring that an overcrossing transmission line will not be adversely affected by a cane fire. Ensuring that adequate clearance is maintained will reduce the probability of a flashover but cannot entirely eliminate it. The only alternative is to remain aware of such an event occurring by encouraging ongoing communications with the cane growers in such areas during the crushing season.

2.4 Asset Handover

Prior to commissioning of all lines construction and refit projects, a handover of the lines asset to key stakeholders (MSP, Technical and Network Solutions team, Lines Strategies team) shall be undertaken separately to other asset classes and include all requirements as detailed in the Asset Strategies - Line Maintenance Principles – Specification, as well as the following, as-built final documentation:

- Layout plan and profile incorporating as-built survey data, in accordance with the Transmission Lines Ratings – Specification.
- Civil schedules & structure drawings showing all maintenance related features including climbing facilities, rigging points and maintenance loads, hardware, insulator assembly drawings, clearance drawings for both operational and maintenance provisions.
- Material specifications and test reports.
- Relevant engineering studies, such as structural analysis, foundations, EMF, noise, earthing & lightning performance studies, including all supporting documentation such as test results.
- Measured earthing resistance and/or earthing commissioning test report for each structure in accordance with the Asset Strategies - Line Maintenance Principles – Specification. Earthing records shall be recorded in SAP.
- Foundation records for each structure shall be recorded in SAP.
- An itemised list of any spares or surplus materials for return to stores or for disposal.
- Phasing Diagram/s issued to the H112 circulation list. As per GDG-300 Drawing Management – Specification.
- Any other essential drawings as detailed in the GDG-300 Drawing Management – Specification.
- Any other relevant detail which will assist maintenance activities.

3. Maintainability

3.1 General

Electricity networks have a growing inventory of transmission structures, which are constantly subject to normal deterioration processes. Maintenance of these assets will consume increasing resources over time, and the constraints under which this maintenance work is planned and carried out are increasing.

Challenges include increasing demands to ensure the health and safety of workers, rising environmental awareness by landowners and the public, and increasing difficulties with obtaining maintenance outages on circuits that are both more heavily loaded each year and constrained by high reliability and availability targets.

The combined effect of these trends means that it is now more important than ever before to ensure that those aspects of transmission line design that impact on long term maintainability and worker safety, are critically reviewed.

The objectives of maintainability design are:

- ensuring safe access to all elements of the transmission line for inspection and maintenance
- compliance with current workplace health and safety legislative requirements
- enhancement of the safety of staff involved in line maintenance
- ensuring that line structures have provision for maintenance loads
- ensuring that structures have provision to facilitate maintenance work
- reduction in the long term cost of line maintenance
- enhancement of line and circuit reliability by increasing maintenance effectiveness
- increased circuit availability by reducing maintenance outage requirements.

3.2 Live Line Working

Unless otherwise defined in the Design Brief, all new transmission line structures shall be designed to enable live line work practices to:

- inspect and test insulator assemblies
- replace insulation assemblies
- replace the suspension insulator attachment brackets
- replace dampers (where these are fitted adjacent to support or termination points)
- replace spacers, splicers, repair rods in-span, using either helicopter or other bare hand approaches with EPV's.

To facilitate live line work, attachment hardware, sockets, split pins, and nuts shall be oriented to facilitate disconnection using live line tooling from the structure, or using bare hand techniques in-span.

3.3 Design Life

The anticipated technical life of a built section varies from less than 40 years to greater than 60 years depending on the its purpose, its maintainability, economics and the environment. In more aggressively corrosive coastal, high humidity, elevated and industrialised locations, the anticipated technical life may not be achievable without major intervention, such as specialised condition based maintenance, refurbishment or refit.

To achieve the target design life for the line, the design of components of any structure shall consider the climatic environment. This will require consideration of corrosion, dissimilar metals, wear rates on components caused by wind and vibration, and any other deterioration processes known to be occurring that could affect the reliability or maintenance costs.

The design of a new transmission line should consider the nature of the line's environment and whether special considerations using more corrosion- resistant materials or finishes will be outweighed by ongoing maintenance costs associated with maintaining standard materials, components, and finishes over the design life of the asset.

3.4 Accessibility

A key requirement for carrying out inspection and maintenance on the components of a transmission line is for those components to be accessible. This requires that the structure site and that the individual components can be accessed.

A practical means of long-term access shall be provided to every structure site to enable maintenance staff and required equipment to be positioned at the structure. Except where the physical siting of the structure precludes achieving road access at a reasonable cost, the minimum access to each structure shall be a road or track suitable for access in dry weather by a conventional 4x4 road vehicle.

There is increasing use of EPV's for maintenance access. However climbing will still be required for structures located in inaccessible locations such as steep mountain ridges, swamps, dense urban areas, etc.

Provision shall be made at the site of every new structure for positioning of an EPV for access to the conductor attachment and support points, where it can be practically achieved at a reasonable cost. Provision shall also be made at each structure site for appropriate crane access to the conductor attachment and support points, where it can be practically achieved at a reasonable cost. Pad provision shall be adequate to position a crane of the height required to access and lift the top conductor or earthwire, and/or a complete crossarm assembly.

Except where it may be otherwise required by the Design Brief all, new structures shall be capable of being climbed and maintained safely to the full height of the structure and to all conductor and earthwire attachment points. The design shall meet all the requirements of the Electrical Safety Rules (Green Book). Structure clearances to permit safe climbing live are shown in Figure 3-1 and Figure 3-2 and these clearances shall be provided on all new structures except where the Design Brief specifically excludes it. In the case of legacy structures where adequate safety clearances do not exist, climbing live may only be undertaken by live line qualified maintenance staff; otherwise climbing may only be permitted with the line de-energised. Safety signage is to be employed wherever there are climbing constraints on a structure.

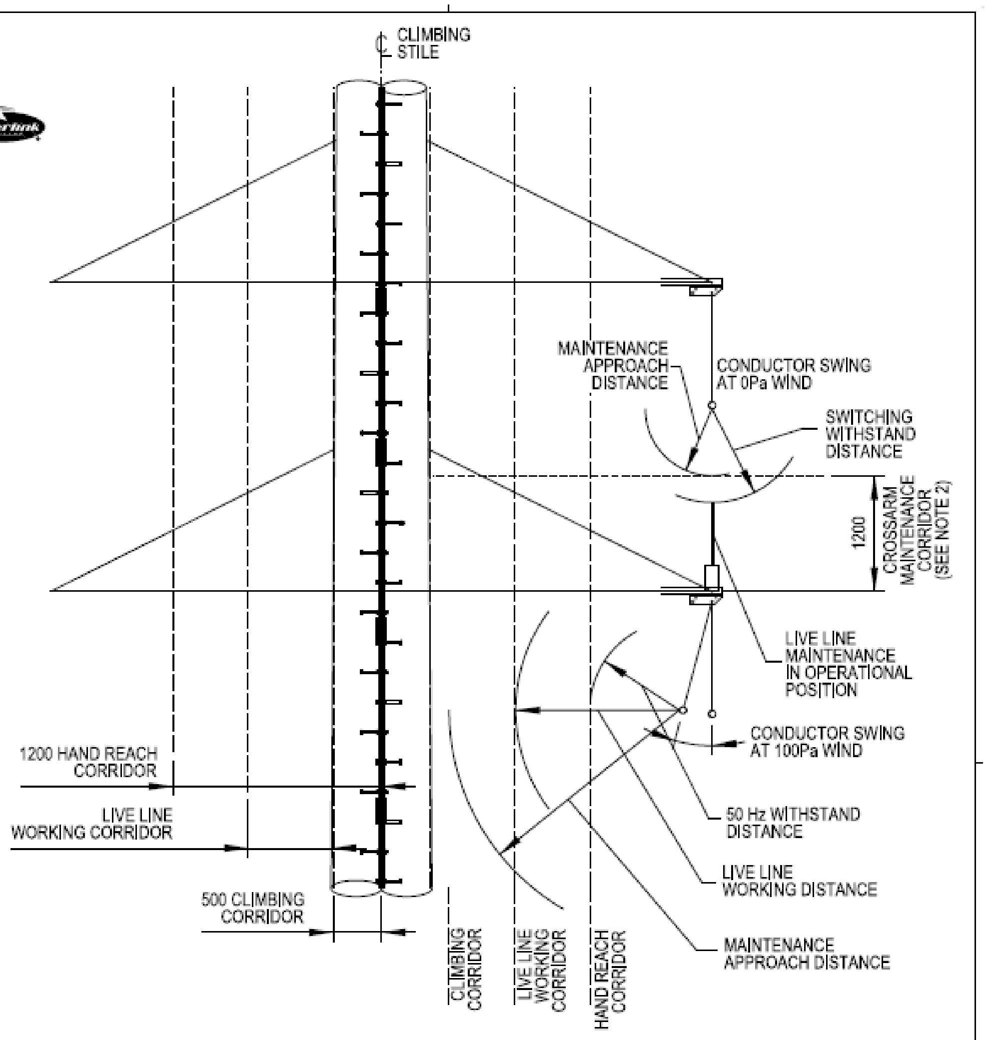
Unless permanent ladders are fitted, step bolts or climbing stiles shall be provided, along with approved lanyard attachment/anchorage points. Where climbing step bolts are provided on towers, a minimum of two diagonally opposed legs shall be fitted. Caged ladders shall not be used.

The climbing corridors and access routes of each structure shall be designed such that a worker using them shall not inadvertently infringe the minimum safe approach distance to the conductors. As shown in Figure 3-1 and Figure 3-2, the climbing corridor for a tower leg shall extend 700mm from each face of the tower, and the climbing corridor for a pole shall extend 1m x 1m using a baseline centred on the climbing aid. Workers bodies shall be considered to be 1m x 1m x 2m high while on rest platforms.

For each new structure design with climbing provision a drawing shall be produced showing as applicable:

- The climbing routes up the main climbing corridors, and along each crossarm.
- The provision of climbing steps, ladders, platforms, or other means of access.
- The safety anchorage provision along each of the access routes.
- The worst safe working and live line work clearances in the vicinity of energised parts.
- Impulse & power frequency clearance maintained to all parts of the structure
- The adequate clearance for live line tooling
- The location and design of rest and working platforms.
- Document the safe hand reach clearance to other circuits (including third party assets) at all voltage levels in close vicinity.

In-span access will be by EPV or where that is not feasible, by helicopter or RPV. Where specified in the Project Scope Report, Line design shall ensure that in-span phase, earthwire and circuit separation shall be adequate to ensure that helicopter access for live line maintenance can be safely undertaken as well as sufficient to avoid mid-span conductor clashing and to meet Powerlink's reliability performance requirements for flashovers.



PHASE TO PHASE OPERATIONAL VOLTS (kV)	LIVE LINE WORKING CORRIDOR	50 Hz WITHSTAND DISTANCE	SWITCHING WITHSTAND DISTANCE	LIVE LINE WORKING DISTANCE	MAINTENANCE APPROACH DISTANCE
132	700	500	900	1200	1400
275	1000	700	1800	2000	2300
330	1000	900	2200	2200	3000

NOTES:
1. ALL DISTANCES ARE IN MM. DRAWING IS NOT TO SCALE.
2. CORRIDOR IS ONLY PROVIDED WHEN MAINTENANCE ACCESS IS REQUIRED TO CROSSARM TIP.

CAD 283x184

CIRCULATION

A ORIGINAL ISSUE

DATE :

Powerlink QUEENSLAND

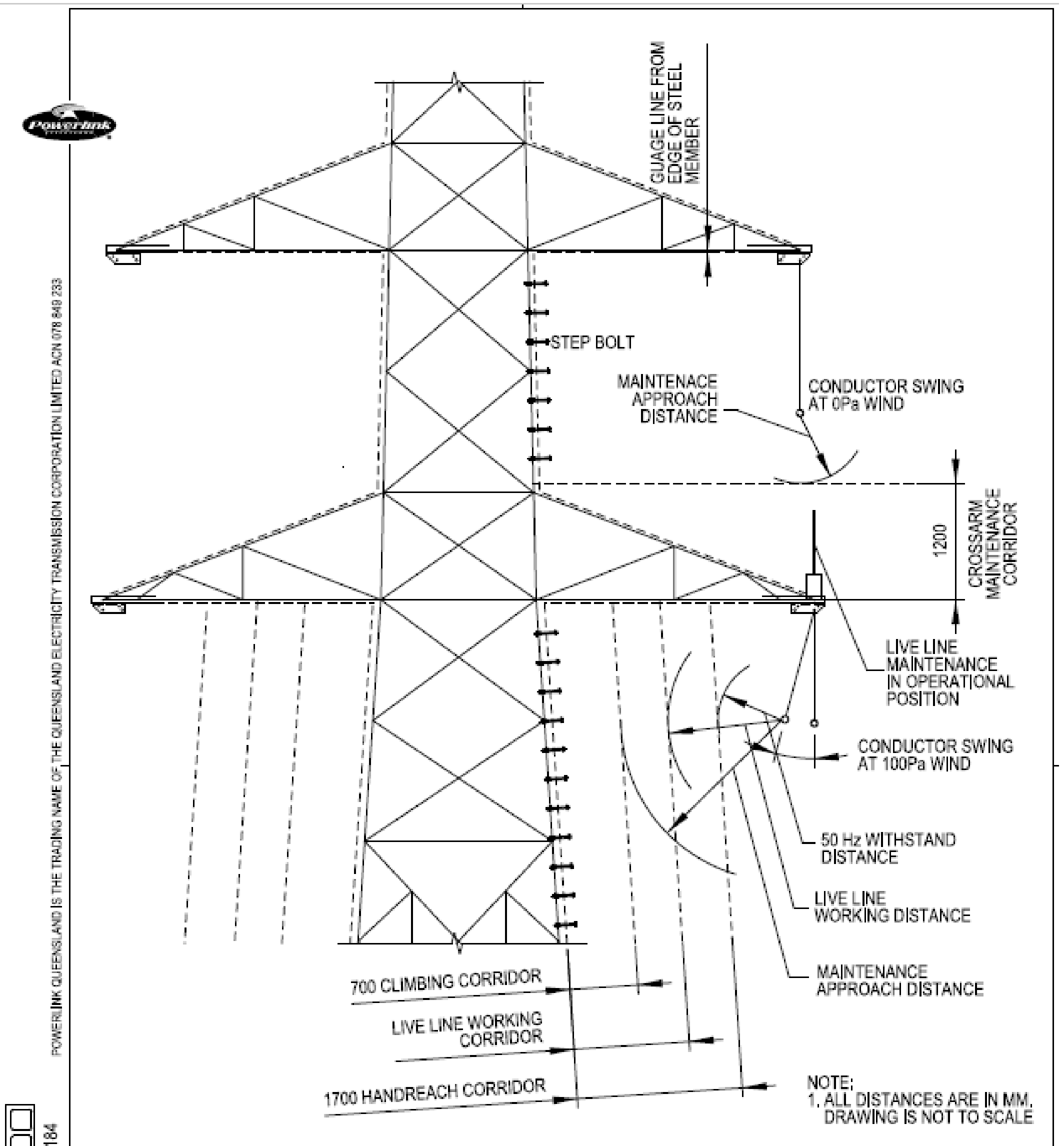
SAFETY CLEARANCES
POLE/ TOWER
WITH ACCESS ON FACE

DESIGNED	DSN CHKD	APPD
CHD	DRAWN	ORIGIN

LOCATION	CONT/ORDER	PROJECT	DRG CLASS

A4 - SKETCH 1 | NEXT SHEET | A

Figure 3-1: Maintenance Clearances for Pole/Tower with face access facility



PHASE TO PHASE OPERATIONAL VOLTS (kV)	LIVE LINE WORKING CORRIDOR	50 Hz WITHSTAND DISTANCE	SWITCHING WITHSTAND DISTANCE	LIVE LINE WORKING DISTANCE	MAINTENANCE APPROACH DISTANCE
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CIRCULATION
A ORIGINAL ISSUE
DATE :

Powerlink

SAFETY CLEARANCES
TOWER

DESIGNED | DSN CHKD | APPD
CHD | DRAWN | ORIGIN
LOCATION | CONT/ORDER | PROJECT | DRG CLASS

A4- SKETCH 2
NEXT SHEET
A

Figure 3-2: Maintenance Clearances – Tower

4. Transmission Line Structures

4.1 General

Self-supporting lattice towers are the most common form of transmission structure in Powerlink's network. Other forms include guyed lattice steel towers, steel poles and concrete poles. While wood poles may be utilised for temporary situations and disaster recovery, they are not permitted as permanent structures. For the purpose of this policy, the "structure" includes the structure, crossarms, brackets, associated steel works, climbing aids, insulator attachment points and the foundation.

Except as noted herein, all new transmission structure designs shall comply with the maintainability requirements of section 3 of this specification, assessed under the principles of Safety in Design and adhere to Powerlink's RPEQ Definitions (Powerlink Context) Framework.

The designs shall include considerations of maintainability and the preparation of appropriate drawings, reflecting maintenance criteria. These should include a Construction and Maintenance Load Drawing and Electrical Clearance Drawings, with relevant live line notes. The drawings shall address the requirements of this document, and illustrate how compliance with each requirement is achieved. Where non-compliances exist, these shall be highlighted and approval obtained on how they will be resolved before construction commences.

The maintainability criteria outlined in Section 3 may be relaxed in situations involving structures for short term use e.g. for a short term supply connections or emergency repair applications, or in cases involving advanced structure development designs where the issue of maintainability is not required. In all such cases, approval of by Asset Strategies shall be obtained before the design is approved.

All components of a new structure design must be capable of being maintained in a safe and reliable condition. In particular, all components on which the safety of a worker is directly dependent (climbing aids, attachment points, crossarms etc.) must be capable of easy inspection and maintenance.

When new structure designs are being prototyped, special attention shall be given to ensuring that the design provisions for maintainability have been met. In particular, attention should be paid to elements related to the safety of maintenance personnel:

- climbing steps and ladders;
- fall arrest anchorages
- live line working and safe working electrical clearances
- provision of working points and rest platforms
- effectiveness of any special fittings or tooling attachments required for maintenance activities.

The construction of any transmission line structure shall be to Powerlink's specifications and shall incorporate checks of local site and ground conditions to ensure the suitability of the structure for the site.

4.1.1 Earthing

Commissioned transmission structures are to be earthed to provide a path to ground for fault current. The structure's footing resistance must be low enough to ensure that substation protection systems will see any electrical fault on the structure and act to isolate that fault. Additional earthing may be required to provide adequate lightning performance. The design target footing resistance is:

- ≤ 5 ohms within 2.5 km of a substation
- ≤10 ohms for the balance of the line. Given the practical difficulty of achieving this result on a long line with variable topography and soils, a statistical approach may be used – e.g. 98% < 20 ohms.

Lower target footing resistances to the values depicted above may be required to meet the lightning performance targets of critical transmission lines or due to revised inspection and test frequencies.

During faults on the network, a voltage gradient will exist between the structure and surrounding earth constituting a potential shock hazard for a person in the immediate vicinity.

All structures in high risk locations within close vicinity to private and public swimming pools, MENs, playgrounds, large public or community buildings, large sporting and recreational facilities and domestic dwelling shall have this potential step and touch hazard assessed for that particular site using probabilistic methods in line with AS/NZS 7000, EG-0, the Queensland Electrical Safety Code of Practice and the Lines Maintenance Principles Specification. Risk mitigation in the form of grading rings, insulation or barriers shall be designed, installed and verified as compliant by test.

A risk of transferred potential must be addressed in situations where there is metallic infrastructure in the immediate vicinity of the structure. Again, this risk must be assessed on a site-by-site basis. Obvious above ground risks such as metal fencing, steel building framing and cladding, and other conductive structures shall be included, as well as known underground risks such as wires, conductive pipes, and reinforced concrete foundations and bodies of water such as swimming pools and dams. Where the risk of injury or damage is not negligible or SFAIRP, cost effective reduction measures such as the installation of insulating sections into wires and pipes, shall be implemented. Earthing assessments shall also consider capacitive coupling risks and align with requirements set out in the DTS – Management of Co-Use Applications for Easements – Guideline as well as relevant Australian and International Standards.

The earthing design and selection of materials by default shall deter theft, with the following exceptions:

- temporary works
- where public access is restricted through the use of barriers
- located in highly corrosive soils
- directly bonded or in close vicinity to a substation or other third party earth mat
- Involves a bespoke solution due to the presence of a cathodic protection system or to manage the corrosion risk in or near other buried metallic objects, transmission structures, substations, industrial plants or traction systems
- Sufficiently remote such that the likelihood of theft is negligible due to reduced accessibility.

In the absence of an earthing study demonstrating compliance to the safe operation of the network, where practical, structures that do not employ an OHEW/OPGW shall have a direct underground earth bond to adjoining structures.

Foundation reinforcing cages shall be electrically continuous and bonded to the super-structure to avoid any foundation damage due to lightning or fault currents.

4.1.2 Signage

All transmission line structures shall be fitted with permanent signs to provide information and hazard warnings to asset maintenance staff and to the public. At a minimum, each structure shall carry information relating to:

- ownership and contact telephone number or website
- structure and circuit identification numbers
- hazard and Do Not Climb advice to the general public
- critical safety advice such as the presence of asbestos paints, heavy metals, radiation or other harmful substances.

All signs shall be installed at such a height to be clearly read from the normal approach direction to the structure. Where a structure is located in an area frequented by members of the public, it will be necessary to ensure that the public hazard/warning signs are installed on two or more faces of the structure. Signage shall be made of materials which are UV resistant and have a service life of the design life of the assets to which they are mounted.

Details of the sizes, specific wording, materials, specific locations, and fixings are provided in the approved SPF drawings set for Overhead Transmission Lines Signage and General Arrangement drawings. All permanent signage shall adhere to Asset Strategies – Line Maintenance Principles – Specification.

4.2 Lattice Steel Towers

In addition to the general requirements set out in 3.1 above, lattice steel towers shall be designed to comply with AS 3995 Australian Standard for the Design Of Steel Lattice Towers and Masts and the criteria outlined in the following sections.

4.2.1 Corrosivity

Corrosivity within Queensland varies considerably depending on location, and is influenced by a large range of factors including proximity to the ocean, elevation, exposure to prevailing winds, and effects from vegetation and pollution (e.g. road and industrial). Powerlink utilises the system in Australian Standard AS 4312 Atmospheric Corrosivity zones in Australia to classify existing structure locations, and all structures are assigned a Structure Corrosion Region classification (in SAP) to assist with asset management Inspection systems are used to verify corrosion performance over time and confirm the appropriateness of the classification.

Built Sections are classified with a single BS Corrosion Region, which specifies their routine maintenance inspection start timing and frequency. Both individual structure and Built Section corrosion region classifications can be found in SAP and are geospatially displayed in the Powerlink GIS. While proposed structure locations cannot be mapped, the available information provides significant information on the probable corrosivity of any new location.

Requirements for structure design with regard to corrosion are:

- In general, the nominal minimum section thickness shall be 5mm.
- For standard steel tower construction under normal conditions, the standard corrosion system for 50 year life is hot dip galvanising. Upgraded protection systems shall be used for high and very high corrosion environments (C4 and C5) where the required design life would not otherwise be achieved. Galvanised bolts used in tower construction are always the first components to need replacing, even in a mildly corrosive environment. In high and very high corrosion environments (C4 and C5) consideration should be given to using more highly corrosion–resistant bolts, nuts and washers than normal galvanised tower bolts. For standard steel tower construction under aggressive conditions, standard galvanising will not provide a 50-year life, and a duplex system is likely to be required, with additional corrosion resistance provided by paint applied over galvanising as part of line construction.
- The standard foundation system is reinforced concrete piers. Where steel piles are used, to overcome difficult soils or soft ground, a condition monitoring system shall be built in to the design. Where short steel leg stubs are used with reinforced concrete piers, care shall be taken to ensure that that the stub is electrically connected to the reinforcing steel cage before the concrete is poured, to ensure an effective connected path to earth for lightning discharge currents, or system fault currents.
- Where lines cross corrosive and/or other environments that may prematurely age line components, the line design or protection systems used need to be appropriately upgraded where possible. For example, where steel pile foundations are installed in marine or swampy environments, the steel below ground shall be electrically connected and a lead brought out to an above ground test tag. The test tag allows checking with a copper sulphate half-cell or attachment of sacrificial anodes or an impressed current cathodic protection.

Any such cathodic protection system shall be designed and installed in accordance with the electrical regulations and appropriate standards. The design shall be optimised for each structure site and shall detail inspection, maintenance and replacement criteria. The detailed design requirements for each system shall be recorded in the Maintenance Manual for the project, for subsequent inspection and maintenance works.

4.2.2 Rest Platforms

Rest platforms shall be provided at the waist on all lattice towers, or just below the lower main conductors on structures with no natural waist.

Where the tower height to the waist exceeds 30m, further rest platforms shall be provided on the main tower body climbing leg(s), spaced nominally at 15 m maximum intervals. Rest platforms are not required in the tower superstructure.

Guyed structures with vertical legs shall have rest platforms at maximum 15m intervals from the ground.

Work platforms (or appropriately located steel work) shall be provided inside the arms of lattice steel strain cross arms, and at other locations on the structure where workers may be required to be positioned for periods of time while undertaking maintenance tasks. Angle iron steps shall be provided on all earthwire peaks to create an effective working platform.

For towers with a height in excess of 60 metres, a suitable platform shall be provided at the overhead earthwire peak to allow a worker to transfer between a helicopter and the tower.

Wherever possible, consideration is to be given to the location of rest platforms and similar structural aggregations, to their potential to act as a building site for nesting birds. Locations directly above suspension and vertical bridging insulators should be avoided, to reduce the potential risk of bird droppings/streamers adversely affecting the insulation and causing a power flashover. If for any reason this is not practical, bird deterrent fittings are to be arranged for these locations.

4.2.3 Climbing Anchorage Points

Unless designed exclusively for EPV access, climbing corridors and the access routes along all crossarms and earthwire peaks, shall be permanently fitted with 15kN minimum failing load anchorage points for safety harness, (21kN where two workers may be attached). This provision shall include a 21kN attachment for a fall arrest rope at the very top of the superstructure above each climbing leg.

All towers designed to be climbed must have provision for full attachment at all times when more than 2.0m above the ground, including during climbing, descending, moving along crossarms, and at working points.

4.2.4 Rigging Points and Maintenance Loads

Structures shall have rigging points provided on crossarms, earthwire peaks and other maintained areas, to enable maintenance procedures to be carried out effectively and safely.

Crossarms and earthwire peaks shall be designed to carry conventional construction and maintenance rigging loads without overloading. These rigging loads shall be shown in the structure drawings and shall relate back to the construction and maintenance procedures that are planned to be used on the structure.

The Construction Loads Drawing shall include a brief description of the load cases and the underlying assumptions made for construction and maintenance practice.

4.2.5 Temporary Earthing Facilities

All structures shall have provision for the attachment of temporary earthing clamps, adjacent to each conductor and earthwire/OPGW attachment point.

Structures which have no flat surfaces suitable for the attachment of temporary earthing clamps, shall have earthing plates welded in at suitable locations near each conductor and earthwire.

Each earthing point shall be large enough to attach a minimum of two flat face tail clamps and shall have two 14mm holes.

Painted towers (or towers to be painted) shall have an earthing plate fitted on each crossarm. Earthing plates shall have a minimum of two attachment bolts.

4.2.6 Anti-Climb Barriers

All structures shall be fitted with barriers to prevent unauthorised access. All anti-climb barriers shall have provision for maintenance access across and/or through them. The type of anti-climb barrier shall be suitable for the tower location.

Where barriers are less than 3m from the ground at a climbing leg, ladder access over the top of the barrier is acceptable. To facilitate ladder access a suitable ladder support point shall be provided at the climbing leg(s).

Where the anti-climbs on a climbing leg are more than 3 m above ground, the frame shall be fitted with a ladder support.

For poles, climbing provision shall be sufficiently located above ground to be non-accessible to the public without the use of a climbing aid.

4.2.7 Wildlife Barriers

In locations where it is likely that wildlife will access the tower, barriers suitable to deter the particular animal of concern shall be installed.

4.2.8 Communications Facilities

OPGW and ADSS downlead cables shall be located on a lattice tower such that climbing routes and the use of fall arrest anchorage points are not impeded, and normal maintenance activities are not constrained.

Cable junction boxes shall be located above the anticlimbing barrier, and below the main conductor level. Junction boxes shall be attached to tower steelwork using designated brackets. Provision shall also be made for rigging points and horizontal steelwork to effectively create a working platform.

The addition of a communication's antennae to a transmission line tower shall only occur by means of a fully engineered and individually RPEQ approved installation.

Communications antennas are often of such a size, and mounted at such a height, that they have the potential to add significant static and wind loads to the structure. Climbing access shall not be impeded by antennae placement. Electrical clearances from antennae to energised components must be maintained. The tower earth mat must be assessed for safety and performance compliance.

Climbing aids shall be retrofitted to current transmission line standards prior to installation of communications antennas. Access to communications antennas on transmission line towers shall only be by line workers with approval to climb. Communications technicians shall not access these structures.

Refer to DTS – Co-location of Telecommunication Equipment – Specification for a detailed list of all communications facilities requirements.

4.2.9 Modification to Existing Towers

Where changes are made to a structure, which do not exceed the original design conditions, detailed structural evaluation is generally not required e.g. “like for like” member replacement or reconductoring without exceeding the diameter, weight and tension of the original conductor. The review process shall incorporate the principal of Safety in Design.

Where minor changes are made to a structure, structural evaluation is generally limited to the sections of the structure logically affected e.g. superstructure checking for replacement of standard earthwire with optical fibre earthwire.

Where structural changes are significant, the structure needs to be evaluated for the impacts on its overall capability to perform its design function.

In all cases, the maintainability of the areas affected by the changes shall be assessed prior to commencement of fieldwork, and access provisions upgraded as required.

When modifying towers a decision has to be made whether to conform to original design standards or to current design standards. Over the last 40 years, structural standards have changed significantly and upgrading to current standards can result in significant costs and increased security over the original design and may not be justifiable.

Even small changes to a tower can have a significant effect on tower strength, especially on earlier, more highly loaded designs. In some cases only a conceptual check will be required, whilst on others a detailed analysis may be necessary especially where loading capability drawings or data do not exist.

4.3 Poles

4.3.1 Steel Poles

Steel poles have been utilised for transmission lines structures for over 40 years. They offer an un-guyed self-supporting structure in urban and other sensitive areas as an alternative to the greater visual impact of steel towers. They have been used in both single and double circuit configuration at voltages up to 275kV, in both suspension and tension configurations. The steel pole structure includes the foundations, the pole, the crossarms, the attachment points and the ground stays (in some cases). Additional earthing, signage and personnel access devices are addressed in section 4.1 above.

The required life and reliability of steel pole structures is achieved by:

- design of structure to match the life and reliability criteria
- purchase of quality structure components that meet design requirements
- construction of structures congruent with the local environment
- regular/routine inspections of the structures
- condition based examinations of structures and selected components.

Engineering details of each pole shall be recorded in SAP to enable inspection and sampling of the steel pole population for maintenance. Details would include manufacturing details, foundation details, and defects discovered – including whether these have been repaired or not. These details and information relating to maintenance of the structures shall also be recorded in an appropriate maintenance manual for the construction contract.

4.3.2 Concrete Poles

Concrete poles have been utilised for transmission line structures for over 30 years. In the mid-1980s, increasing use was made of spun concrete poles for transmission lines in either a single pole or two-pole structure configuration. Concrete pole suspension and tension structures have continued to be used at voltages up to 132kV.

For the purpose of this document, concrete pole structures include their foundations, the pole, the pole cap, the crossarms, the ground stays and the attachment points. Additional earthing, signage and personnel access devices are addressed in section 4.1.

The required life and reliability of concrete pole structures is achieved by:

- design of structure to match the life and reliability criteria
- purchase of quality structure components that meet design requirements
- construction of structures congruent with the local environment
- regular inspections of the structures
- condition based examinations of structures and selected components.

Maintenance activities on concrete poles must be carried out in a manner consistent with the requirement of the preventative maintenance procedures developed under the RCM (or similar) process as an integral part of the design.

To enable sampling of the concrete pole population for maintenance, it is essential that engineering details of each pole be recorded in SAP. Details would include manufacture date, manufacturing plant, pole size, and pole strength and foundation conditions. These details and information relating to maintenance of the structures shall also be recorded in an appropriate maintenance manual.

4.3.3 Wood Poles

Wood poles were once used extensively for transmission line constructions up to 132kV. However, the use of larger conductors and the limited availability of larger poles has restricted their use to lower voltages. Powerlink now only uses wood poles for temporary or emergency restoration structures.

For the purpose of this document, wood poles includes any foundations, the pole itself, any stays, the crossarms and the attachment points.

Maintenance activities on wood poles must be carried out in a manner consistent with the requirement of the RCM (or similar) process undertaken as part of the asset design.

To enable the effective maintenance of wood pole structures it is essential that engineering details of each pole be recorded. Details would include manufacture date, manufacturing plant, pole size, and pole strength and foundation conditions. These details and information relating to maintenance of the structures shall be recorded in an appropriate maintenance manual.

5. Insulators

5.1 General

The continued safe operation of a transmission line is dependent on the quality of the conductor support insulators on structures. The insulators and their support hardware provide the critical linkage between conductors and structures and are required to perform under onerous concurrent electrical, environmental, and mechanical stresses. Typically, transmission corporations have used and continue to use a variety of insulator types, which best match the transmission lines required operating characteristics. Insulators are characterised by various factors including:

- material composition, e.g. ceramic (glass, porcelain) or non-ceramic insulators (silicone rubber)
- insulator unit configuration, e.g. disc, long rod, or post
- pollution design
- mechanical strength, e.g. electro-mechanical strength, cantilever strength.

The insulator “asset” as defined by Powerlink in SAP includes the connecting hardware, together with insulator grading tube, corona rings, yoke plates and any other components directly associated with the insulator assembly.

Operating characteristics of insulators used in any new assemblies shall be recorded for inclusion in the associated maintenance manual. In addition, for each new major project or major insulator refurbishment project, a specific drawing shall be produced for the insulator assemblies including lengths and clearances for the assembly in the structure window. The insulation installed on every transmission line structure is recorded in SAP. For new transmission lines and during maintenance and refurbishment of the transmission line insulation, the details of the installed insulation shall be recorded and entered into SAP as part of the project.

Insulation electrical performance shall be co-ordinated with substation assets and lightning performance requirements considering the desired reliability.

5.2 Insulator Types

Powerlink’s transmission line fleet uses both cap and pin and non-ceramic insulator types.

In 1998, following successful trials over the previous 10 years, Powerlink adopted a change to its transmission line insulation selection policy and began the general installation of non-ceramic insulators on new transmission lines. Since 1999 more than 2500 transmission line structures have been constructed with silicone rubber insulators. They have been used in conventional suspension, tension and bridging locations as well as for insulated cross arm assemblies. This insulator population has been monitored in detail to determine long-term performance, resulting in a change from the 1998 policy to the current policy outlined below.

In 2020, toughened glass insulators were also approved for re-introduction and use, subject to about a review of their location.

Lines Strategies Team shall be informed of any departure from approved transmission line insulators.

Pin corrosion of disc insulators is the dominant failure mode for Powerlink’s transmission line insulators. New disc insulators are currently purchased with zinc sleeves to extend the pin life by at least 20% depending on environment. The design and specification of insulators shall incorporate features to economically address this dominant failure mode.

Insulation selection shall generally be undertaken in accordance with Approach 1 in IEC TS 60815-1, using past experience to confirm and select insulators and their respective dimensions for greenfield and brownfield applications with consideration to the site pollution severity (SPS). Greenfield and brownfield installations shall adopt a minimum SPS of Medium.

5.3 Hardware Requirements

Hardware shall be in accordance with the Technical Specification and supported by the nominated applicable Australian and International Standards nominated in those Specifications as well as:

- standard mechanical and electrical ratings
- standard hardware mating in accordance to HB 331
- design in such a manner to avoid insulator clashing with standard sub-conductor spacing
- safe adjustment of the assembly and control of differential safe or insulator string adjustment on bundled conductors
- provisions to support live line replacement
- rigging to allow for the raising and lowering of conductors
- all non-ceramic insulators shall be provided with corona rings or tubes
- hardware corona rings shall be utilised on assets 200kV and above, or where public interaction dictates, to increase the onset and extinction voltages for hardware assemblies.

5.4 Surge Arresters

The use of line surge arresters is limited to critical transmission lines that are unable to meet lightning performance targets in a practical and cost-effective manner throughout the asset life cycle utilising of conventional mitigation methods such as shielding, grounding or insulation improvement. Refer relevant Equipment Strategy.

5.5 New Conventional Transmission Lines

New transmission lines using conventional tower or pole structures shall be designed and constructed using disc insulators. The use of toughened glass discs may be restricted in vandal prone areas. Experience has shown that vandalism is a rare event, which, when it does occur, is more likely to occur on the outskirts of major population centres. Local operating experience is the best guide as to whether this restriction should apply in any particular area.

The policy of favouring discs for conventional insulation applications is based on a number of criteria including:

- an historical understanding of disc insulator performance and disc insulator life cycle across Queensland
- a recognition of the long economic life of the majority of Powerlink's disc insulator population in comparison to the life expectancy of non-ceramic insulators
- recent problems experienced with bird attack on non-ceramic insulators
- operating and maintenance challenges associated with assessing end of life for non-ceramic insulators.

It is recognised that alternate non-ceramic insulator designs are most suitable in some environments. For new permanent transmission lines, Lines Strategies shall be provide input into the application non-ceramic insulators.

The following list indicates typical situations where additional factors may weigh the choice towards non-ceramic insulators:

- High pollution areas (e.g. Silicone rubber insulators have superior performance to discs in contaminated environments).
- Short span work (e.g. Substation entry where discs are more difficult to install and the quantity of non-ceramic insulators will be small).
- Bridging insulators (e.g. where the use of lightweight post non-ceramic insulators can reduce swing clearances required on tension structures).
- Where maintainability is a governing criteria (e.g. at 330kV long disc insulator strings can become difficult to maintain due to weight and string bending, and the use of light weight non-ceramic insulators may significantly improve maintainability).

- Where the transmission line insulation is only required to remain serviceable for less than 20 years, the cost of non-ceramic insulators may offer the most cost effective solution. This situation may apply for construction of a short life 'non-regulated' asset or for re-insulation of a transmission line that has a defined 'end of life'.

The design process for any non-ceramic insulator assembly shall allow for the replacement of the insulator with a similar, but not identical insulator, without major changes to the assembly hardware. This requirement is to eliminate the need for Powerlink to retain unique insulator spares.

The use non-ceramic insulators for permanent installations shall be subject to the undertaking of a bird survey to determine the potential for bird attack. The outcome of the survey shall be a determining factor in the approval to use composite insulators.

5.6 New Non-Conventional Transmission Lines

New transmission lines using non-conventional tower or pole structures e.g. compact designs may be designed and constructed using non-ceramic insulators subject to the completion of a potential bird attack survey and agreed by Lines Strategies Team.

This policy is based on the following criteria:

- non-conventional structure designs are typically more expensive and are used for situations requiring special requirements (e.g. low visual impact, less swingout due to narrow easements, need to match existing line construction)
- in non-conventional structure design the use of non-ceramic insulators is complementary to the overall design and can create an 'acceptable' structure solution.

5.7 Existing Transmission Lines

On existing transmission lines a 'like for like' insulator replacement policy shall be applied during maintenance or refurbishment work if the operational performance of the existing insulators had been deemed satisfactory. This policy means that the same type, size and number of insulators shall be used for insulator replacement.

For transmission line re-insulation projects the specific creepage distance required shall be informed by the operating performance of the existing insulation and the pollution levels as measured from sampled discs. The result may be modified by the need to maintain statutory ground and structure clearances.

If the insulator performance has been unsatisfactory then the insulation shall be redesigned to correct the performance deficiency. When major insulator replacement maintenance or refurbishment is planned then a review of the insulator performance shall be undertaken before commencement of the project.

All insulator replacement projects shall include the production of drawings showing the replacement insulator assemblies and electrical clearances in the structure's superstructure.

6. Conductors

This section applies to all components of conductor systems, including the phase conductors themselves, suspension and strain fittings, compression connectors, mid-span joints, bridging connectors, preformed fittings for repair and protection, vibration dampers, and conductor spacers.

6.1 Fittings

Common practice on phase conductors is to use compression type mid-span joints and compression dead-end fittings, with bridges employing compression lugs connected via bolted palms. On older transmission lines with smaller conductors, dead-end fittings commonly consisted of a bolted hinge clamp with the bridging tail being connected using compression connectors or parallel groove clamps. Hardware shall be in accordance with the Technical Specification and supported by the nominated applicable Australian and International Standards.

Fittings for the conductor shall include:

- compression dead ends with terminal pads and matching compression lugs appropriate for the conductor rating
- AGSU's for conductor suspension attachments
- trunnion clamps over preformed armour for bridging conductor support
- stockbridge dampers for conductor damping, with the addition of a combination spacer/damper system for quad conductor arrangements
- rigid spacers for sub-conductor separation
- aerial markers
- provision for helicopter and UAV access to in-span hardware fitting.

Damaged conductor systems, in particular midspan joints, will require the use of specially designed fittings to enable the conductor capacity to be restored. These repair processes and fittings shall be designed to ensure that conductor ratings are not reduced as a result of the local repair.

All compression fittings shall be type tested to ensure correct pairing of fitting conductor and recommended compression dies.

Midspan joints and midspan joint repair device locations shall be recorded as "equipment" in SAP under the Span functional location and adhere to the asset handover and commissioning requirements detailed in the Asset Strategies – Line Maintenance Principles – Specification.

6.2 Conductor Types

Phase conductors used in Powerlink's transmission line construction principally employ two types of bare aluminium conductor – Aluminium Conductor Steel Reinforced - Galvanised (ACSR/GZ) and All Aluminium Alloy Conductor (AAAC). Single-phase conductor configurations are generally used at 110kV and 132kV, whereas multiple conductor bundle configurations are used at higher voltages. Generally, Powerlink's 275 and 330kV lines assets use twin bundle horizontal arrangement and 500kV quad arrangement.

Other less common conductor types used for phase conductors include:

- aluminium Alloy conductor Steel Reinforced (AACSR/GZ)
- aluminium Conductor Steel Reinforced- Aluminium Clad (ACSR/AC)
- all Aluminium Conductor (AAC).

The development of a new conductor system shall consider:

- the normal and emergency electrical loads that the line must carry and long-term tensile strength loss due to annealing
- the operating voltage

- the maximum conductor surface voltage gradient to avoid interference complaints
- typical span lengths and mechanical loads
- the environment that will be encountered along the route signalling any special anti-corrosion requirements that should be added to the conductor specification
- aeolian vibration design considerations shall be in accordance with the design principles outlined in Appendix Y of AS7000. All conductors within the tension range outlined in LDM-001 shall be fully-damped
- sub-conductor oscillation (for bundled conductors)
- surface reflection in areas of high public presence
- electrical losses, interference and corona
- resilience to fault current and lightning.

The key mechanical characteristics of the selected conductor are required to enable sag/tension calculations to be carried out as part of the line layout system using PLS_CADD or a similar system. These characteristics include:

- conductor breaking load
- stress/strain curves
- creep characteristics
- thermal expansion properties.

The conductor system design and as-constructed details for each built section (including the conductor type and characteristics, the conductor fittings details and the stringing detail) shall be recorded for operation and maintenance in the line's Maintenance Manual. Stringing details to be recorded include pull-out tension and temperature, time and tension in sheaves before final sagging, final sag and temperatures and include any details of problems encountered in the stringing and the remedial measures that were adopted.

Powerlink support the use of High Temperature Conductor (HTC) and High Temperature Low Sag (HTLS) conductor for greenfield and brownfield applications where it can be demonstrated through a comparative study that a HTC or HTLS solution provides a more cost-effective solution over the asset life cycle than traditional conductor technologies, is practical and technically feasible. The comparative study shall consider:

- costs associated with field based trials, re-tooling, staff training and work methods development
- extensive conductor testing to validate performance and properties
- procurement of adequate spare conductor and any specialised associated materials and tooling
- engineering on-costs in the development of new design standards and methodologies
- maintenance practices compatibility including live line
- environmental performance and losses
- operating envelope of the network meeting the required levels of reliability and market obligations.

6.3 Clearances

Minimum ground clearances are set out in Queensland's Electrical Safety Regulations and shown in Table 6-1 below. Powerlink applies a margin to these minima to make allowance for potential errors in sag characteristics of the conductor, creep, annealing, material tolerances, construction inconsistencies, survey inaccuracies and for potential errors in the conductor's maximum temperature under emergency loading conditions. These tolerances are different for greenfield and brownfield installations. The resulting design ground clearances for greenfield application are shown in Table 6-1.

Clearance from energised parts to ground and other features on or in the vicinity are defined in the Queensland Electrical Safety Regulation and shall be determined for the dynamic operation under serviceability and limit state conditions in accordance with AS/NZS 7000.

Other instances where additional clearances to those depicted in Table 6-1 shall be considered where there exists:

- critical environmental areas
- a high risk of air insulation failure due to a bushfire
- to meet CASA requirements
- traversing a waterway or flood plain
- over-spanning Powerlink, railway or other utility asset, with adequate separation to enable safe operation and integrity of all assets in the vicinity
- non-standard over-dimensioned routes
- to meet the ICNIRP guidelines on limiting electromagnetic field exposure and inductive coupling to objects in the vicinity

Table 6-1: Ground Clearance

Line Voltage	Regulation Minimum Ground Clearance	Powerlink's Minimum Ground Clearance (Greenfield)
110/132 kV	6.7m	7.5m
275 kV	7.5m	8.5m
330 kV	8.0m	9.0m
500kV	9.0m	*

* At voltages exceeding 330kV ground clearance is not deterministic and is governed but ICNIRP guidelines on limiting electromagnetic field exposure and inductive coupling to objects in the vicinity.

Except in critical environmental areas, Powerlink restricts vegetation on the easement in the "shadow area of the conductors +6m" to a height of 1m. In critical environmental areas where there are agreed limits to the clearing of existing vegetation, the conductor at its maximum sag shall be the following distances above the mature height of the protected vegetation as described in Section 2 of Powerlink's Vegetation Management Specification. These distances allow for trimming by "Untrained Persons" as defined in the Regulations and are as follows:

Table 6-2: Vegetation Clearance

Line Voltage	Vegetation Clearance
≤ 330kV	6.0m
500kV	8.0m

7. Overhead Earthwires

7.1 General

This section covers all types of metallic earthwires, OHEW's, and those having overhead glass fibre cores for communications, OPGW's. It does not include 'All-dielectric Self-Supporting' (ADSS) cable.

Lightning is the largest single cause for line outages on Powerlink's network. To meet the reliability target for transmission lines, most transmission lines on Powerlink's network are fitted with overhead earthwires. Transmission lines usually have two earthwires, except for some of the early 132kV designs. Many transmission lines have at least one Optical Fibre Ground Wire containing optical fibres.

The primary function of overhead earthwires is to intercept lightning strikes by shielding phase conductors from most direct strokes thereby reducing the probability of a flashover and a consequential line outage. This attribute is particularly important within several km of a substation where effective shielding can reduce the probability of a direct lightning stroke to conductors entering the substation.

Failures of optical fibres in OPGW's can have far reaching effects on SCADA, protection signalling and voice communications. The reliability and longevity of all overhead earthwires is critical because replacement is difficult and expensive requiring outages of the phase conductors below. Replacement of OPGW is especially difficult, as additionally it requires the redirection of communication circuits. The relevant equipment strategy shall detail the minimum strand diameter to meet the class rating for charge transfer.

By providing a parallel network of earth connections between adjacent structures and substations, overhead earthwires provide an important supplementary safety role by reducing the level of step and touch potential at a structure associated with a phase to ground fault at that structure. Adequate fittings and bonding of the overhead earthwires are important in achieving this.

7.2 Overhead Earthwire Types

A wide variety of OHEWs and OPGWs currently exist on Powerlink's transmission line system, typically ranging up to 19mm. OPGW's shall have a minimum of 48 fibres. Refer relevant Equipment Strategy.

7.3 Overhead Earthwire Functions

The design overhead earthwire functions are:

- to shield the transmission line conductors from a direct strike by lightning
- to intercept lightning strikes to the protected transmission line without strand damage
- to conduct a proportion of power frequency fault current resulting from a phase to earth fault, without damage to the earthwire or fittings until protection clears the fault
- to sag less than the phase conductors to minimise the risk of a mid-span flashovers
- to reduce the fault level at the connecting substation
- to provide a low impedance multi-paralleled path to earth for induced currents and fault currents
- aeolian vibration design considerations shall be in accordance with the design principles outlined in Appendix Y of AS7000. All OHEW and OPGWs within the tension ranges outlined in LDM-001 shall be fully damped.

7.4 Design & Hardware Requirements

The overhead earthwire design and hardware requirements shall be shall be in accordance with the Technical Specification and supported by the nominated applicable Australian and International Standards nominated in those Specifications as well as:

- OHEW/OPGW minimum aluminium strand diameter of 3mm
- withstand the fault current imposed on the overhead earthwire by the maximum anticipated power frequency fault current at the structure, for the backup protection clearing time
- sag should nominally be no more 80% of phase conductor sag at EDT
- for new structures, earthwires shall be bonded unless otherwise advised
- for existing structures, earthwire bonding will be on an as needs basis

- OPGW's, fittings and joint enclosures must ensure mechanical stress is not applied to the optical fibres and that the fitting prohibits moisture from entering the fibres
- AGSU's shall be fitted at suspension points
- dead-end fittings for OPGW shall be wedge type; OHEW may be either wedge or compression
- large diameter OHEW, greater than 19mm require compression fittings
- vibration protection structural rods shall be installed at all overhead earthwire support points with an additional layer of helically fitted vibration damper structural rods to all OPGW to provide additional protection
- OHEW's with an OD less than 12.5mm, SVCs shall be applied to inhibit vibration-induced fatigue
- OHEW's with an OD greater than 12.5mm, stockbridge type dampers shall be applied
- for all OPGW, stockbridge type dampers shall be applied over armour
- provision for helicopter and UAV access to in-span hardware fitting
- for a design life (including all fittings) to match the structure design life in consideration of corrosivity at all line locations
- OPGW expansion loop and jointing provision to be located above anti-climbing device with sufficient length for cable end to be lowered to ground level plus 10 metres
- maximum spacing between downlead clamps of 2 metres and shaped such to maintain the supplier's recommended bending radius
- overhead to underground fibre transitions shall employ bushfire mitigation.